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COPY #3

Preliminary Amendment

UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of

Jerry B. Roberts

Serial No.
(a divisional application of
application Serial No. 08/589,930,
filed September 30, 1997;
Allowed December 14, 2000

Art Unit: 2673

Examiner: Lao, L.

Filed: Herewith

For: *METHOD OF AND APPARATUS FOR THE ELIMINATION OF THE EFFECTS OF INERTIAL INTERFERENCE IN FORCE MEASUREMENT SYSTEMS, INCLUDING TOUCH-INPUT COMPUTER AND RELATED DISPLAYS EMPLOYING TOUCH FORCE LOCATION MEASUREMENT TECHNIQUES*

Hon. Commissioner of Patents
and Trademarks
Washington, DC 20231

Dear Sir:

This application is a divisional application of the above-identified parent application.

The claims of this divisional application are as follows:

--1. A method of measuring force and/or torque to be applied to a mechanically movable or disturbable system, including, where desired , objects associated therewith and portions of force measuring apparatus itself, that comprises, sensing one or more components of force and/or torque applied to the system by deliberate forces acting thereupon to provide force and/or torque measurements uncorrected by inertial interference motion effects that arise;

intentionally moving and disturbing the system in various ways while the said deliberate forces ultimately to be measured are not applied and are allowed to remain at zero, in order to generate measurements that enable calibration of the system that renders the same less prone to force measurement errors due to motions of the type created by said moving and disturbing. --

--3. Apparatus for measuring force and/or torque to be applied to a mechanically movable or disturbable system, including, where desired, objects associated therewith and portions of force measuring apparatus itself, having, in combination, means for sensing one or more components of force and/or torque applied to the system by forces acting thereupon to provide force and/or torque measurements uncorrected for inertial interference motion effects that arise; means for sensing lineal and/or rotational acceleration of the system in response to such inertial interference motions; and means for correcting the uncorrected force and/or torque measurements in response to the acceleration sensing to achieve elimination from the measurements of the effects of such inertial interference. --

--4. Apparatus as claimed in claim 3 and in which said uncorrected force measurements are made and said acceleration is sensed for all relevant degrees of freedom of motion in a plurality of respective channels, and means is provided for adding different linear combinations of the acceleration-sensing channels in turn to each channel of force measurement, with coefficients of combinations chosen such that the resulting sums reflect the desired force measurements substantially free of inertial motion interference errors. --

--5. Apparatus as claimed in claim 4 and in which means is provided to derive time derivatives including at least a set of the second order derivatives of the uncorrected force measurements and to enter the same in different linear combinations of each order in turn in each channel of force measurement further to correct the same. --

--6. Apparatus as claimed in claim 5 and in which calibration means is provided including means for intentionally moving and disturbing the system in various ways while the force ultimately to be measured is allowed to remain at zero, with means for generating a correction matrix the elements of which comprise the desired coefficients of combination to achieve the corrections of the force measurements in each channel. --

--7. Apparatus as claimed in claim 6 and in which means is provided for deriving the coefficients of combination for the correcting channels at the display. --

--8. Apparatus as claimed in claim 3 and in which the mechanically movable or disturbable system is a weighing system. --

REMARKS

The allowed parent application contains claims directed to touch panel display systems. The method of the invention, however, is more generically applicable, as pointed out in the original specification, (bottom of pages 1 and 66, for example) to force measuring applications in movable mechanical systems generally.

Claims 1 and 2 herein therefore track the allowed touch panel display method claims 13 and 14, respectively, but more generically recite use in a mechanically movable or disturbable system as to which the cited prior art of the D'Angelo patent is no more anticipatory than to the allowed touch panel display claims—all other claim limitations being identically incorporated into the claims of this divisional application.

Apparatus claims 3-7 similarly track allowed claims 22-25, and claim 8 is specific to the weighing embodiment also taught in the application.

It is accordingly believed that this divisional application is thus in condition for allowance, and such action is therefore respectfully requested.

Any costs required by this filing, and/or for any required extensions of time, petition for which is hereby made, may be charged to Deposit Account No. 18-1425 of the undersigned attorney.

Respectfully submitted,

RINES AND RINES

By: ______________________

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DESCRIPTION OF PREFERRED EMBODIMENT

The preferred embodiment embraces the system of my said copending application, now modified to incorporate the improvement of the current invention. These improvements, as before summarized, reside in the novel type and arrangement of accelerometer capacitances as additional input channels, as shown in Fig. 4; and the extension of the firmware processing performed in the microprocessor system to support the method of the invention, as flow-charted in Fig. 5. In addition, the static sensor channels have been increased in number and the associated sensors relocated to the corners with pairs of horizontally mounted coil springs now employed.

Fig. 1 depicts the force and torque sensing platform 5 in use as a computer touch input device for locating and otherwise measuring touches delivered to the display device 2, shown as a CRT display montior 11. The touch force generated by the user's hand 1 at point P passes through CRT display monitor 2, then in parallel through a tilt-swivel base 3 and stabilizer bar and bracket 4 provided with platform device 5 to a top plate 7 and the

condition:

$$f_u = A \ddot{f}_u + B a . \qquad (2$$

"C" is defined to be the six by twelve matrix formed by appending the rows of "B" after the corresponding rows of "A". There may be "n" measurement vectors in a calibration set collected as described.

Assume that a six by "n" matrix of uncorrected force readings "R_u" is formed by taking the first six components (derived from 71, Fig. 5) of each measurement vector, in order, as a column of "R_u". Let twelve by "n" matrix of correction channel readings "R_{cc}" be formed by taking the the last twelve components (derived from 72 and 73, Fig. 5) of each measurement vector, in order, as a column of "R_{cc}". Then we have:

$$R_u = C R_{cc} . \qquad (3$$

In general, no "C" will exactly solve equation 3 -- it is inconsistently overdetermined, due to redundant but slightly noisy data. Yet many will very nearly do so, since "C" is at the same time underdetermined, in that some modes of disturbance are

represented poorly or not-at-all in the calibration data. Thus we must look for a best fit "C", but not usually the one that gives the absolute minimum residual on the determining data. Rather, we wish to find that matrix to use for "C" which minimizes the expected value of the sum of the squares of the components of the error matrix "E" for:

$$E = R_{u2} - C\,R_{cc2} , \qquad (4$$

where "R_{u2}" and "R_{cc2}" constitute a second set of independently determined calibration data on exactly the same installation, but with "C" determined from the original calibration data "R_u" and "R_{cc}".

We begin from the singular value decomposition of "R_{cc}":

$$R_{cc} = U\,W\,V^{T} , \qquad (5$$

where column orthogonal matrices "U" and "V", and diagonal matrix "W have the usual definitions, and the calibration program calculates these using standard methods. The calibration program then obtains "C" from:

$$C = V\,W_{z}^{-1}\,U^{T}\,R_{u} . \qquad (6$$

"W^{-1}" may be obtained from "W" by replacing each diagonal

element "w_{ii}" with its scalar reciprocal "$1/w_{ii}$". "W_z^{-1}" is obtained in a similar manner, except that zero is substituted for "$1/w_{ii}$" for each singular value "w_{ii}" which is too small. By "too small" is meant a determination assigned heuristically by the program to any singular value which is smaller than a certain percentage (such as one percent) of the greatest singular value, or which has an absolute value too close to the noise floor. This noise floor may be observed in the singular values obtained from data gathered as though performing a calibration, but with measurement groups artificially triggered in the absence of any disturbance. The best heuristics are a function of the application and the exact embodiment, and are determined empirically by repeated trials of differing relative and absolute thresholds; that pair of values is then chosen which actually minimizes expression 4 for multiple independently collected data matrices.

While a serviceable value of "C" may often be obtained by using "W^{-1}" for "W_z^{-1}" in expression 6, use of the latter provides not only better average correction,

What is claimed is:

1. In a touch-input computer and related supported display employing touch force location measurements, a method of eliminating [the] errors [that may be] introduced into force and/or torque measurements by undesired inertial interference motions of one or more of the support, mechanical system of the display and/or force measuring apparatus itself, that comprises, sensing one or more components of force and/or torque applied to the display by touch forces to provide force and/or torque measurements uncorrected for inertial interference motion effects that [may] arise; sensing lineal and/or rotational acceleration of the display in response to such inertial interference motions; and correcting the uncorrected force and/or torque measurements in response to the acceleration sensing to ~~reflect~~ achieve substantial elimination from the measurements of the effects of such inertial interference.

2. A method as claimed in claim 1 and in which said uncorrected force measurements are made and said acceleration is sensed for all relevant degrees of freedom

of motion in a plurality of respective channels, and different linear combinations of the acceleration-sensing channels are added in turn to each channel of force measurement, with coefficients of combinations chosen such that the resulting sums reflect the desired force measurements substantially free of inertial motion interference errors.

3. A method as claimed in claim 2 and in which time derivatives including at least a set of the second order derivatives of the uncorrected force measurements are derived and entered in different linear combinations of each order in turn in each channel of force measurement further to correct the same.

4. A method as claimed in claim 3 and in which calibration is effected from the supported display by intentionally moving and disturbing the same in various ways while the touch force ultimately to be measured is allowed to remain at zero, in order to generate a correction matrix the elements of which comprise the desired coefficients of combination to achieve the corrections of the force measurements in each channel.

5. A method as claimed in claim 4 and in which coefficients of combination for the correcting channels are derived in situ at the display.

6. In a touch-input computer and related supported display employing touch force location measurements, a method of eliminating the errors that may be introduced into force and/or torque measurements by undesired inertial interference motions of one or more of the support, mechanical systems of the display and/or force measuring apparatus itself, that comprises, sensing one or more components of force and/or torque applied to the display by touch forces to provide a plurality of channels of force and/or torque measurements uncorrected for inertial interference effects that may arise; deriving time derivatives including at least a set of the second order derivatives of the uncorrected force measurementsand subtracting entering the same in different linear combinations of each order in turn from ~~in~~ each channel of uncorrected force measurement, with coefficients of combination chosen such that the resulting sums reflect the desired force measurements substantially free of inertial motion interference errors.

70

itself, ~~that comprises sensing two or more~~ components of force and/or torque applied along corresponding input channels to the system by forces acting thereupon to provide force and/or torque measurements uncorrected for inertial interference motion effects that arise; correcting at least one channel of force measurement by applying corrections derived from other input channels of the uncorrected force measurements, such that the output of said one channel of force measurement is rendered substantially free of inertial interference errors

11 ~~12~~. A method as claimed in claim 11 and in which the deriving and applying of corrections is mathematically substantially equivalent to deriving corrections which are time derivatives, including in at least one instance the second time derivative of some or all of the uncorrected force measurements or linear combinations of the same, and from an uncorrected force measurement of another channel to yield said one channel of force measurement ~~which is substantially free of inertial interference.~~

8 ~~9~~. Within a method for measuring aspects of the location of application of a force to an object, a method of measuring force and/or torque applied to the object that comprises, sensing two or more components of force and/or torque applied to the object by forces acting thereupon, to provide force and/or torque measurements uncorrected for inertial interference motion effects that arise; correcting at least one force measurement by applying corrections derived from other uncorrected force measurements, such that said one force measurement is rendered substantially free of inertial interference errors.

measuring apparatus itself, that comprises, sensing one or more components of force and/or torque applied to the system by forces acting thereupon to provide force and/or torque measurements uncorrected for inertial interference motion effects that may arise; sensing lineal and/or rotational acceleration of the system in response to such inertial interference motions; and correcting the uncorrected force and/or torque measurements in response to the acceleration sensing to reflect elimination from the measurements of the effects of such inertial interference.

9. A method as claimed in claim 8 and in which said uncorrected force measurements are made and said acceleration is sensed for all relevant degrees of freedom of motion in a plurality of respective channels, and different linear combinations of the acceleration-sensing channels are added in turn to each channel of force measurement, with coefficients of combinations chosen such that the resulting sums reflect the desired force measurements substantially free of inertial motion interference errors.

10. A method as claimed in claim 9 and in which time derivatives including at least a set of the second order derivatives of the uncorrected force measurements are derived and extended in different linear combinations of each order in turn in each channel of force measurement further to correct the same.

11. A method as claimed in claim 10 and in which calibration is effected ~~from~~ the ~~supported~~ display by intentionally moving and disturbing the same in various ways while the touch force ultimately to be measured is allowed to remain at zero, in order to generate a correction matrix the elements of which comprise the desired coefficients of combination to achieve the corrections of the force measurements in each channel.

12. A method as claimed in claim 11 and in which coefficients of combination for the correcting channels are derived in situ at the display.

13. A method of measuring force and/or torque to be applied to a ~~mechanical~~ touch panel display system, including, where desired objects associated therewith and portions of forces measuring apparatus itself, that comprises, sensing one or more components of force and/or torque applied to the system by deliberate forces acting thereupon to provide force and/or torque measurements uncorrected by inertial interference motion effects that may arise; deriving time derivatives including at least a set of the second order derivatives of the uncorrected force measurements and [illegible] ~~entering~~ the same in different combinations of each order in turn ~~in~~ from each channel of uncorrected force measurement, with coefficients of combination chosen such that the resulting sums reflect the desired force measurements substantially free of inertial motion interference errors.

14. A method of measuring force and/or torque to be applied to a ~~mechanical system~~ touch panel display system, including, where desired objects associated therewith and portions of force measuring apparatus itself, that comprises, sensing one or more components of force and/or torque applied to the

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system by deliberate forces acting thereupon to provide force and/or torque measurements uncorrected by inertial interference motion effects that may arise; ~~deriving time effects that may arise~~; intentionally moving and disturbing the system in various ways while the said deliberate forces ultimately to be measured are not applied and are allowed to remain at zero,, in order to generate measurements that enable calibration of the system that renders the same less prone to force measurement errors due to motions of the type created by said moving and disturbing.

15. In a touch-input computer and related supported display employing touch force location measurements apparatus for eliminating the errors that may be introduced into force and/or torque measurements by undesired inertial interference motions of one or more of the support, mechanical system of the display and/or force measuring apparatus itself, having, in combination, means for sensing one or more components of force and/or torque applied to the display by touch forces to provide force and/or torque measurements uncorrected for inertial interference motion effects that may arise; means for sensing lineal

and/or rotational acceleration of the display in response to such inertial interference motions; and means for correcting the uncorrected force and/or torque measurements in response to the acceleration sensing to reflect substantial elimination from the measurements of the effects of such inertial interference.

16. Apparatus as claimed in claim 15 and in which means is provided for making said uncorrected force measurements and sensing said acceleration for all relevant degrees of freedom of motion in a plurality of respective channels, and different linear combinations of the acceleration-sensing channels in turn to each channel of force measurement, with coefficients of combinations chosen such that the resulting sums reflect the desired force measurements substantially free of inertial motion interference errors.

17. Apparatus as claimed in claim 16 and in which means is provided for deriving time derivatives including at least a set of the second order derivatives of the

uncorrected force measurements and for entering the same in different linear combinations of each order in turn in each channel of force measurement further to correct the same.

18. Apparatus as claimed in claim 17 and in which calibration means is provided comprising means by intentionally moving and disturbing the supported display in various ways while the touch force ultimately to be measured is allowed to remain at zero, in order to generate a correction matrix the elements of which comprise the desired coefficients of combination to achieve the corrections of the force measurements in each channel.

19. A method as claimed in claim 18 and in which means for deriving coefficients of combination for the correcting channels is operated in situ at the display.

20. In a touch-input computer and related supported display employing touch force location measurements, apparatus for eliminating the errors that may be introduced into force and/or torque measurements by undesired inertial

interference motions of one or more of the support, mechanical systems of the display and/or force measuring apparatus itself, having, in combination, means for sensing one or more components of force and/or torque applied to the display by touch forces to provide a plurality of channels of force and/or torque measurements uncorrected for inertial interference effects that may arise; means for deriving time derivatives including at least a set of the second order derivatives of the uncorrected force measurements and individually entering the same in different linear combinations of each order in turn ~~in~~ from each channel of uncorrected force measurement, with coefficients of combination chosen such that the resulting sums reflect the desired force measurements substantially free of inertial motion interference errors.

21. In a touch-input computer and related supported display employing touch force location measurements, apparatus for eliminating the errors that may be introduced into force and/or torque measurements by undesired inertial interference motions of one or more of the support, mechanical systems of the display and/or force measuring

apparatus itself, having, in combination, means for sensing one or more components of force and/or torque applied to the display by touch forces to provide a plurality of channels of force and/or torque measurements uncorrected for inertial interference effects that may arise; means for intentionally moving and disturbing the supported display in various ways while the touch force ultimately to be measured is not applied and is allowed to remain at zero, in order to generate measurements that enable calibration of the supported display system that renders the same less prone to force measurement errors due to motions of the type created by said moving and disturbing.

22. Apparatus for measuring force and/or torque to be applied to a ~~mechanical~~ touch panel display system, including, where desired, objects associated therewith and portions of forcemeasuring apparatus itself, having, in combination, means for sensing one or more components of force and/or torque applied to the system by forces acting thereupon to provide force and/or torque measurements uncorrected for

inertial interference motion effects that [may] arise; means for sensing lineal and/or rotational acceleration of the system in response to such inertial interference motions; and means for correcting the uncorrected force and/or torque measurements in response to the acceleration sensing to reflect elimination from the measurements of the effects of such inertial interference.

23. Apparatus as claimed in claim 22 and in which said uncorrected force measurements are made and said acceleration is sensed for all relevant degrees of freedom of motion in a plurality of respective channels, and means is provided for adding different linear combinations of the acceleration-sensing channels in turn to each channel of force measurement, with coefficients of combinations chosen such that the resulting sums reflect the desired force measurements substantially free of inertial motion interference errors.

24. Apparatus as claimed in claim 23 and in which means is provided to derive time derivatives including at least

a set of the second order derivatives of the uncorrected force measurements and to enter the same in different linear combinations of each order in turn in each channel of force measurement further to correct the same.

25. Apparatus as claimed in claim 24 and in which calibration means is provided including means for intentionally moving and disturbing the same in various ways while the touch force ultimately to be measured is allowed to remain at zero, with means for generating a correction matrix the elements of which comprise the desired coefficients of combination to achieve the corrections of the force measurements in each channel.

26. Apparatus as claimed in claim 25 and in which means is provided for deriving the coefficients of combination for the correcting channels in situ at the display.